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**Shin et al.**

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(45) **Date of Patent:** **Sep. 4, 2012**

(54) **POWER CONTROL FOR COMBINED DYNAMICALLY AND PERSISTENTLY SCHEDULED PUSCH IN E-UTRA**

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(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 656 days.

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**Related U.S. Application Data**

(60) Provisional application No. 60/984,993, filed on Nov. 2, 2007.

(51) **Int. Cl.**  
**H04W 52/04** (2009.01)

(52) **U.S. Cl.** ..... **455/522; 455/69; 455/517; 455/452.1**

(58) **Field of Classification Search** ..... **455/517, 455/522, 509, 69, 452.1, 452.2, 67.11, 67.16**  
See application file for complete search history.

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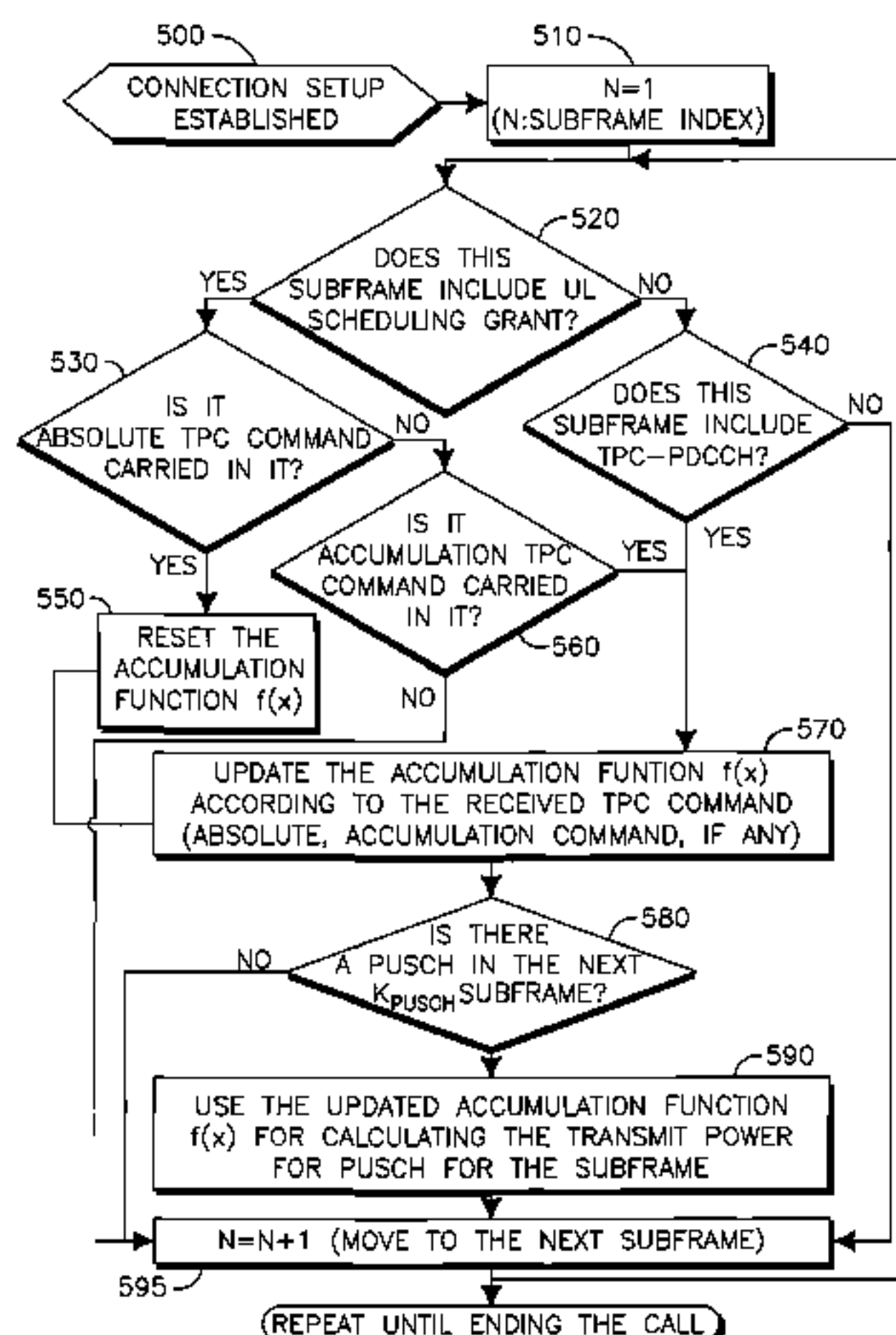
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(57) **ABSTRACT**

A power control scheme for an enhanced Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access (E-UTRA) physical uplink shared channel (PUSCH) is disclosed. In a first embodiment, when an uplink grant is configured for accumulation commands, the wireless transmit/receive unit (WTRU) combines the accumulation commands received in both the scheduling grant and the transmit power control physical downlink control channel. In a second embodiment, when an uplink grant is configured for absolute commands, the WTRU resets the accumulation control function immediately after receiving each absolute transmit power control command and then combines the absolute power control with the accumulation power control.

**14 Claims, 7 Drawing Sheets**



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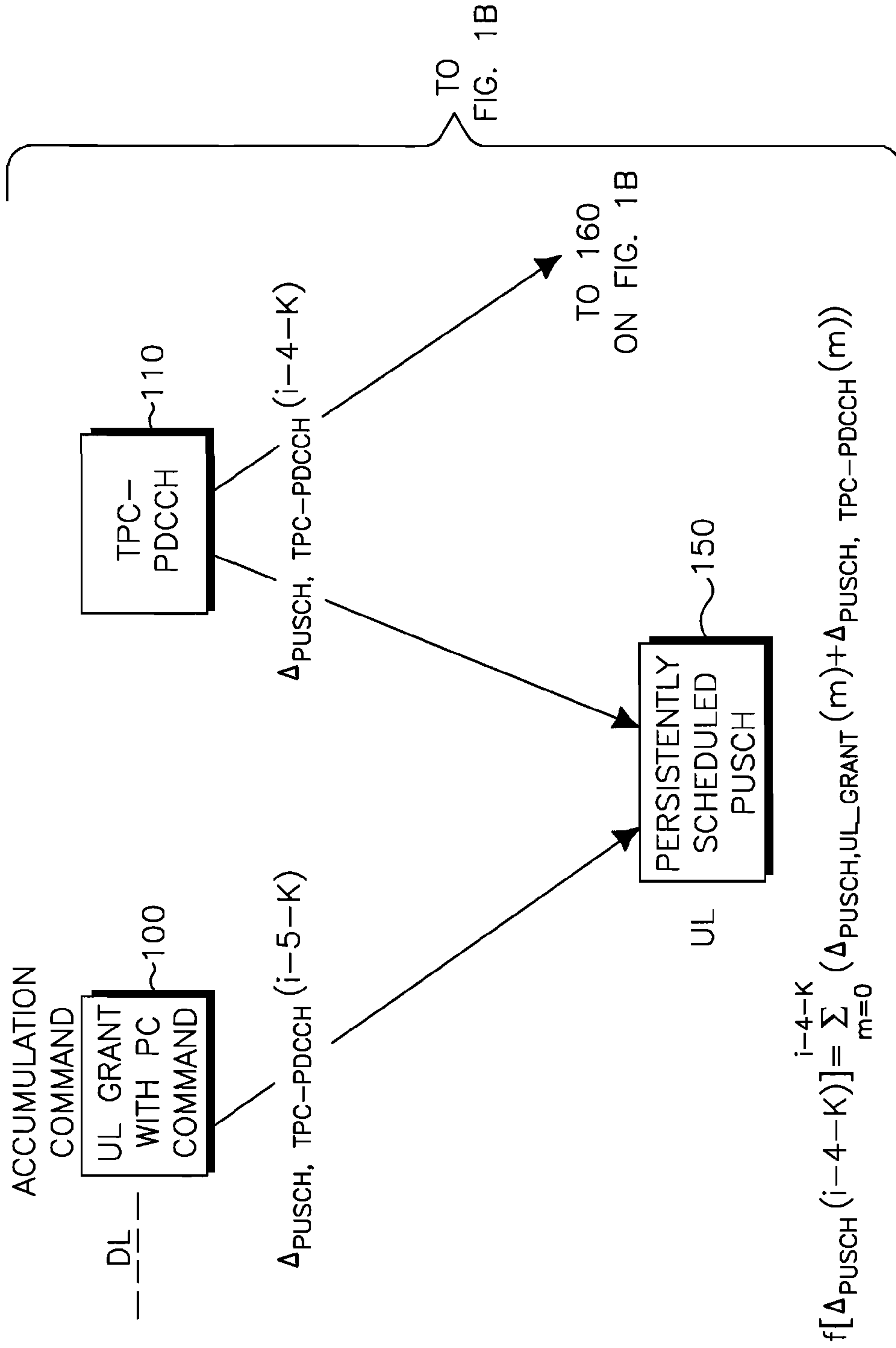
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**FIG. 1A**

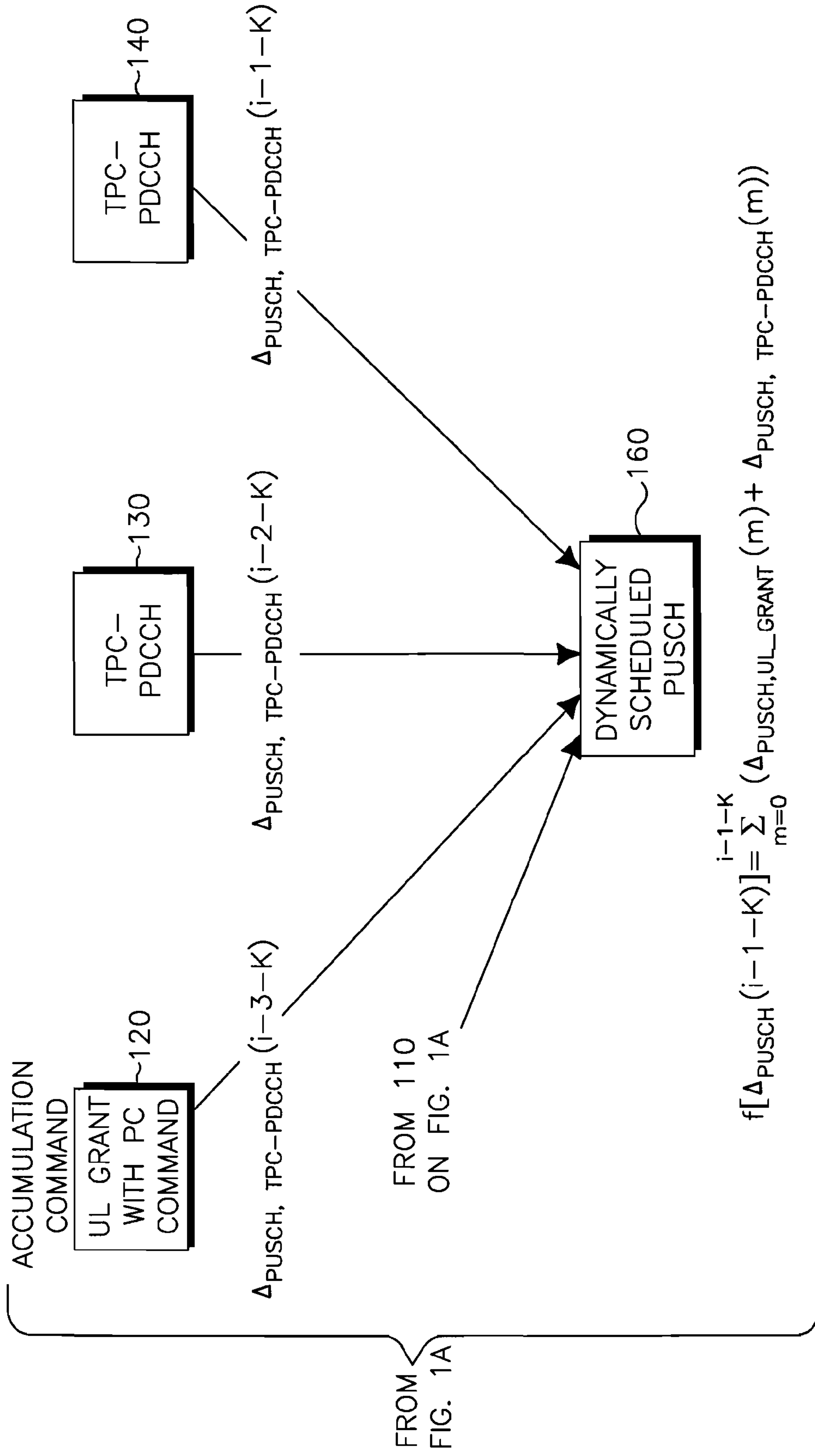
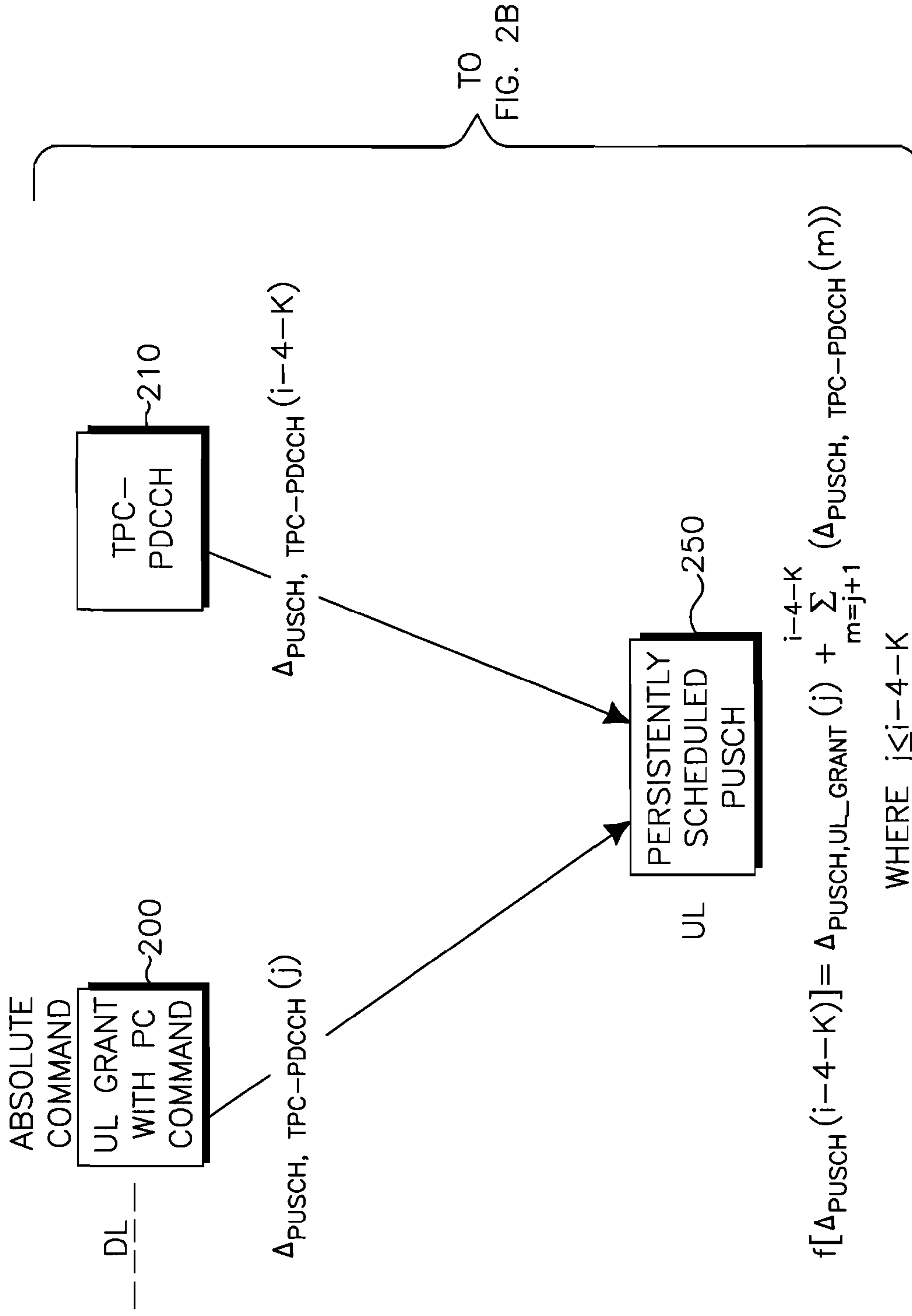


FIG. 1B



$$f[\Delta_{\text{PUSCH}}(i-4-K)] = \Delta_{\text{PUSCH, UL\_GRANT}}(j) + \sum_{m=j+1}^{i-4-K} (\Delta_{\text{PUSCH, TPC-PDCCH}}(m))$$

WHERE  $j \leq i-4-K$

**FIG. 2A**



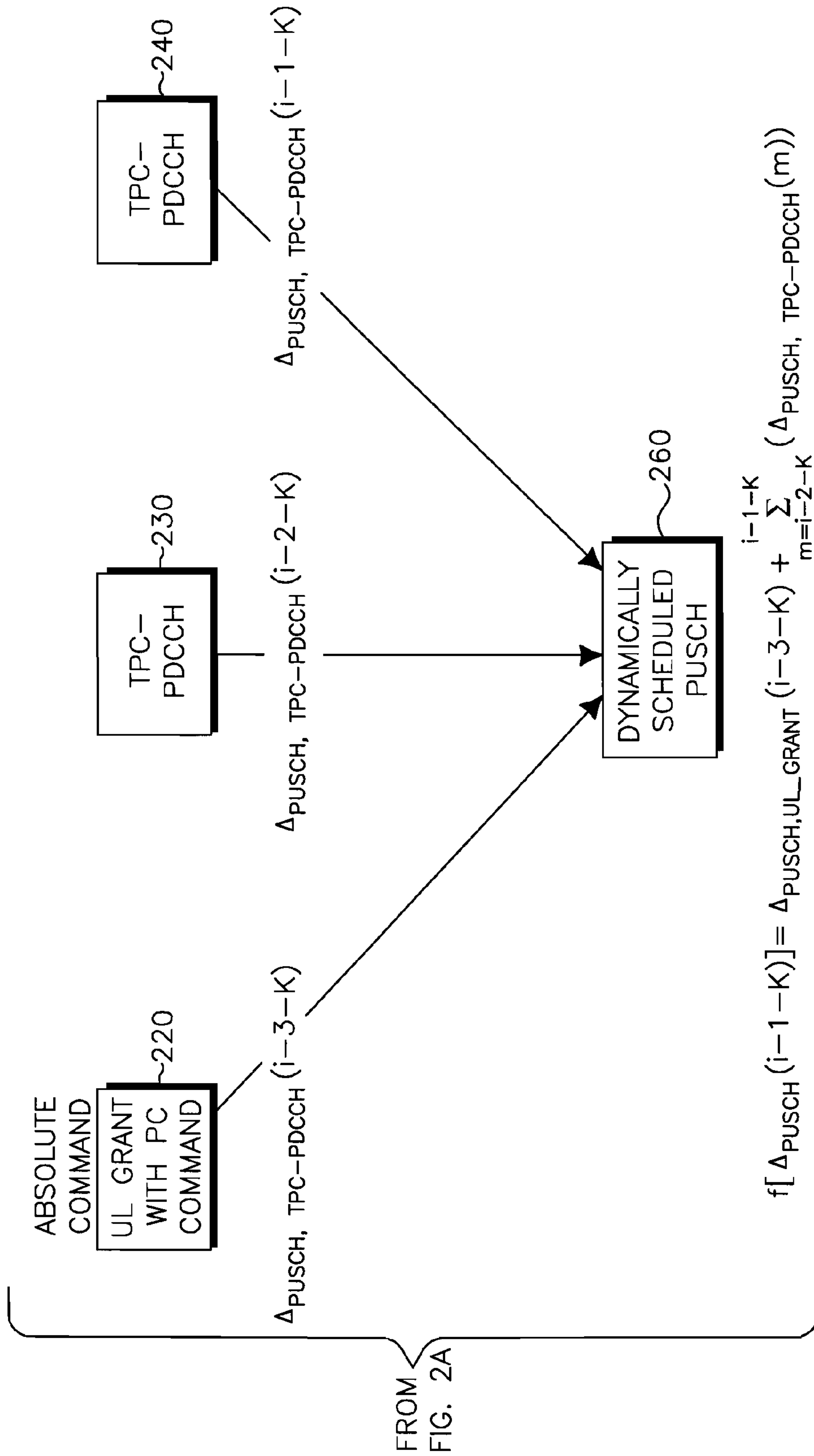
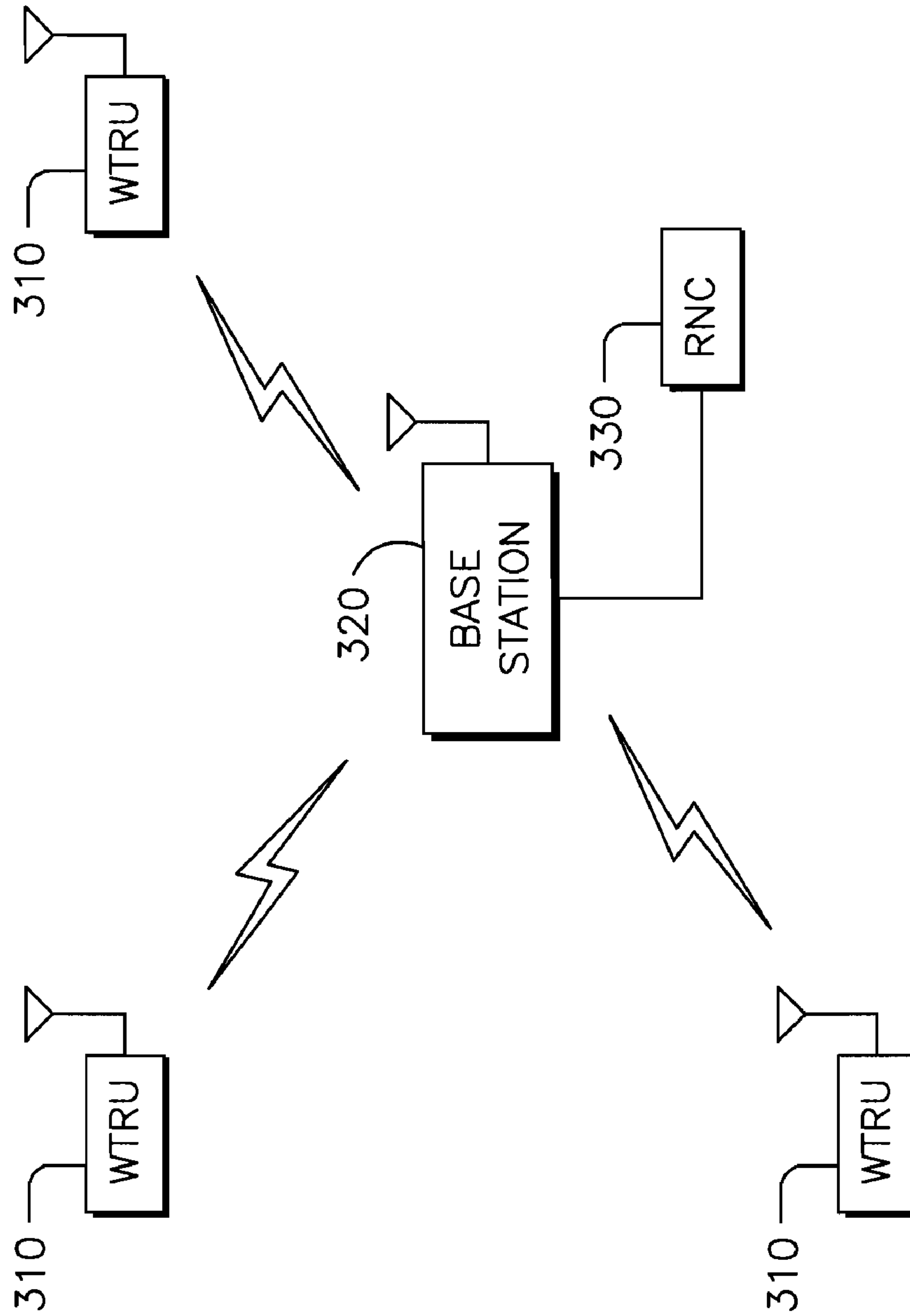


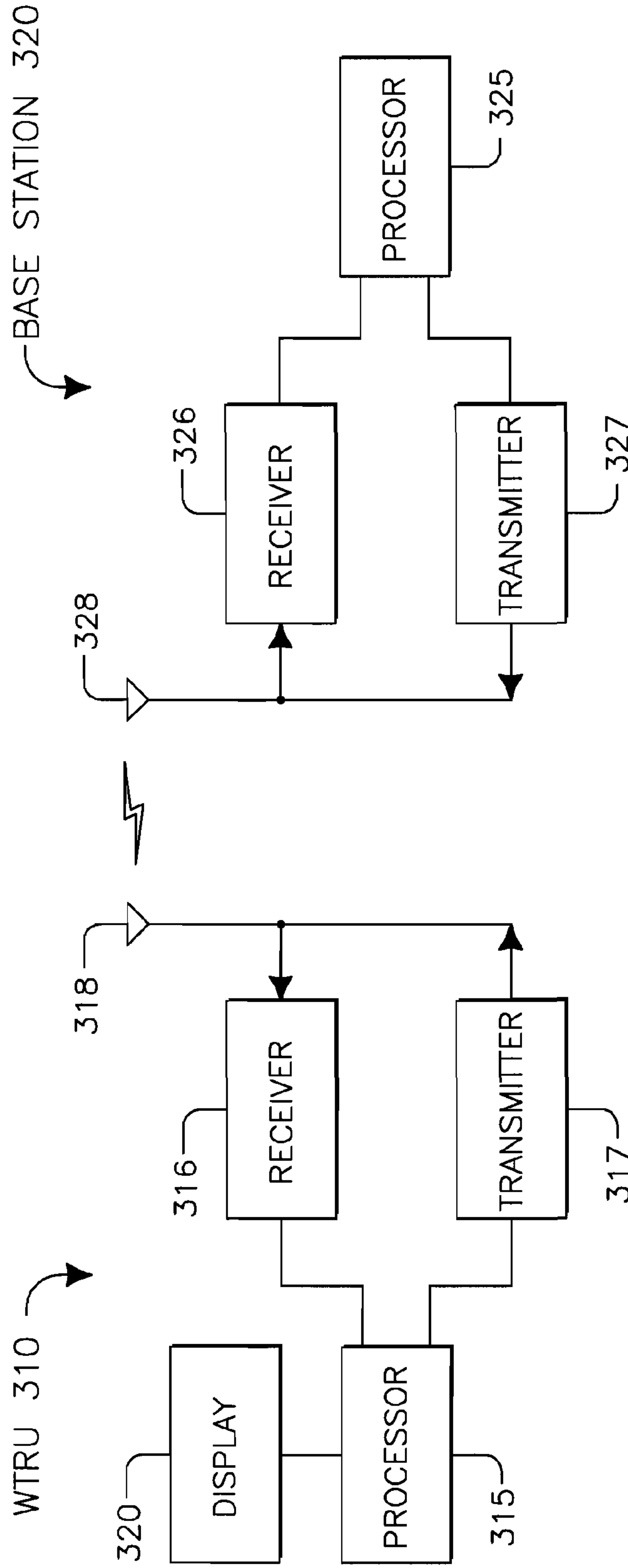
FIG. 2B

300



**FIG. 3**

400



**FIG. 4**



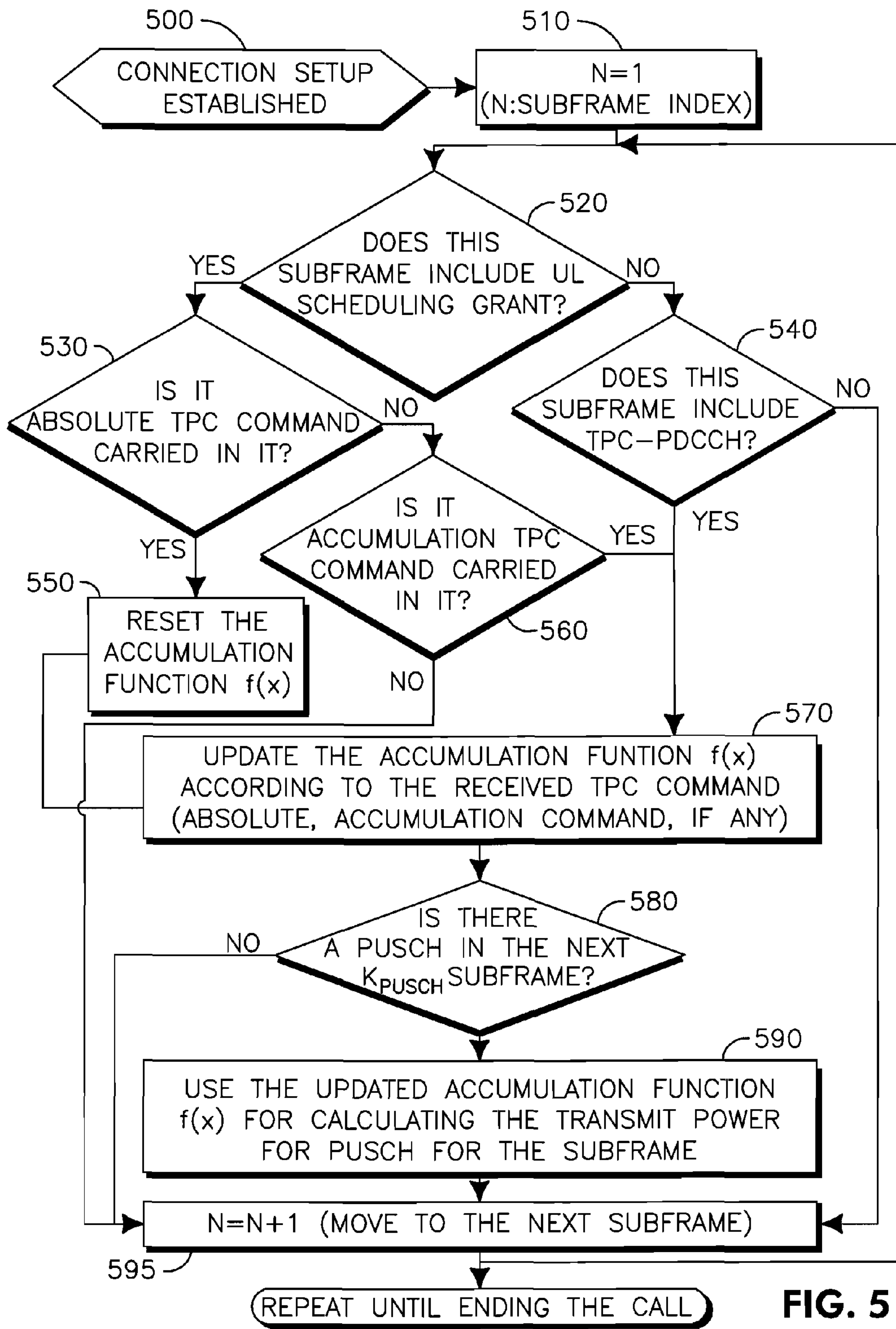


FIG. 5

**POWER CONTROL FOR COMBINED  
DYNAMICALLY AND PERSISTENTLY  
SCHEDULED PUSCH IN E-UTRA**

CROSS REFERENCE TO RELATED  
APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 60/984,993, filed Nov. 2, 2007, which is incorporated by reference as if fully set forth.

FIELD OF INVENTION

The present invention is related to a wireless communication system.

BACKGROUND

The physical uplink (UL) shared channel (PUSCH) power control has two components, an open loop component and a closed-loop component. Both the open and the closed loop components run consecutively, but asynchronously. The procedure is illustrated below, by way of example.

In a given UL subframe  $i$  ( $i=0$  to any number), a PUSCH may be transmitted in the following manner: 1) on a dynamically assigned resource (by an UL grant on a physical downlink (DL) control channel (PDCCH)); 2) on a persistently assigned resource; or 3) not at all.

In a given DL subframe  $n$ , a power control command  $\Delta_{PUSCH}(n)$  for PUSCH power control may be provided in the following manner: 1) within an UL scheduling grant on PDCCH; 2) on a transmit power control (TPC) physical DL control channel (PDCCH), referred to as the TPC-PDCCH<sub>PUSCH</sub>; or 3) not at all.

If the PUSCH is transmitted in the subframe  $i$ , it is transmitted with the power  $P_{PUSCH}(i)$ . In the power control formula below, let  $K_{PUSCH}$  be the delay in the PUSCH power control, i.e., a power control command provided in DL subframe  $n$  ( $n=0$  to any number) will not impact the PUSCH transmit power in subframes prior to subframe  $n+K_{PUSCH}$ .

Power control for PUSCH is described as follows. The power spectral density is controlled by a combination of open-loop and closed-loop techniques. The power spectral density is converted into transmit power by scaling according to the number of assigned resource blocks as indicated in the UL scheduling grant. The transmit power is limited by the maximum allowed power which depends on the wireless transmit/receive unit (WTRU) power class. There is a constant power value applied which is a combination of a cell-specific parameter and a WTRU-specific parameter. The open-loop component uses the downlink pathloss calculated in the WTRU from a reference symbol (RS) received power (RSRP) measurement and signaled RS transmit power. The pathloss in dB is scaled by a cell specific path loss compensation factor. The transmit power is adjusted by a modulation and coding scheme (MCS) variable signaled in each UL scheduling grant. Lastly, the closed-loop component is a specific correction value in dB included in every scheduling grant or jointly coded with other WTRU specific correction values on a TPC-PDCCH<sub>PUSCH</sub>.

The power control formula for PUSCH is defined below:

$$P_{PUSCH}(i) = \min(P_{max}, 10 \log_{10}(M) + P_o + \alpha \cdot P_L + \Delta_{mcs} + f[\Delta_{PUSCH}(i - K_{PUSCH})]) \quad \text{Eq. (1)}$$

where:

the variable  $P_{max}$  is the maximum allowed power (in dBm) that depends on the wireless transmit/receive unit (WTRU) power class;

the variable  $M$  is the number of assigned resource blocks as indicated in the UL scheduling grant;

the variable  $P_o$  is a WTRU specific parameter (in dBm) with 1 dB resolution over a range of -126 dBm to 24 dBm;

the variable  $\alpha$  is cell specific path loss compensation factor (can be set to one to allow full path loss compensation) that has eight values from 0.4 to 1 in steps of 0.1 with one of the possible values being zero;

the variable  $PL$  is the downlink pathloss calculated in the WTRU from a reference symbol received power (RSRP) measurement and signaled reference symbol (RS) transmit power;

the variable  $\Delta_{mcs}$  is signaled by a RRC ( $\Delta_{mcs}$  table entries can be set to zero) modulation and coding scheme (MCS) signaled in each UL scheduling grant;

$\Delta_{PUSCH}$  is a WTRU specific correction value and is included in a UL scheduling grant or jointly coded with other WTRU specific correction values on a TPC-PDCCH<sub>PUSCH</sub>.

The WTRU attempts to detect a TPC-PDCCH<sub>PUSCH</sub> on every subframe except when in discontinuous reception (DRX) mode of operation. The power control formula may be applied to dynamically scheduled PUSCH or to persistently scheduled PUSCH.

For power control in dynamically scheduled PUSCH, the closed-loop correction value is a function  $f[*]$  which represents either an accumulation or absolute value; the mode is signaled semi-statically via higher layers. When a new value of  $\Delta_{PUSCH}$  is received in the scheduling grant (SG),

For absolute control

$$f[\Delta_{PUSCH}(i - K_{PUSCH})] = \Delta_{PUSCH}(i - K_{PUSCH})$$

For accumulation control

$$f[\Delta_{PUSCH}(i - K_{PUSCH})] = \sum_{m=0}^i \{\Delta_{PUSCH}(m - K_{PUSCH})\}$$

For power control in persistently scheduled PUSCH, the function  $f[*]$  represents only accumulation. When a new value of  $\Delta_{PUSCH}$  is received in the TPC-PDCCH<sub>PUSCH</sub>,

$$f[\Delta_{PUSCH}(i - K_{PUSCH})] = \sum_{m=0}^i \{\Delta_{PUSCH}(m - K_{PUSCH})\}$$

Power control for dynamically scheduled and persistently scheduled PUSCH, respectively, is described in the 3rd Generation Partnership Project (3GPP) specification. But, when both PUSCH are simultaneously scheduled as active, there is no solution on how to power control the two PUSCH together. A solution that controls the power of both the PUSCHs together is highly desirable.

SUMMARY

A power control scheme for enhanced Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access (E-UTRA) PUSCH is disclosed.

BRIEF DESCRIPTION OF THE DRAWINGS

A more detailed understanding may be had from the following description, given by way of example and to be understood in conjunction with the accompanying drawings wherein:



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FIGS. 1A-1B show an example of power control for combined dynamically and persistently scheduled PUSCH when the UL grant is configured for accumulation commands;

FIG. 2A-2B show an example of power control for combined dynamically and persistently scheduled PUSCH when the UL grant is configured for absolute commands;

FIG. 3 shows an example wireless communication system including a plurality of wireless transmit/receive units (WTRUs), a base station, and a radio network controller (RNC);

FIG. 4 is a functional block diagram of a WTRU and the base station of FIG. 3; and

FIG. 5 is a flow chart of an example embodiment.

## DETAILED DESCRIPTION

When referred to hereafter, the terminology “wireless transmit/receive unit (WTRU)” includes but is not limited to a user equipment (UE), a mobile station, a fixed or mobile subscriber unit, a pager, a cellular telephone, a personal digital assistant (PDA), a computer, or any other type of user device capable of operating in a wireless environment. When referred to hereafter, the terminology “eNB” includes but is not limited to a Node-B, an Evolved Universal Terrestrial Radio Access Network (UTRAN) Node-B, a E-UTRAN Node-B, an evolved Node-B, a base station, a site controller, an access point (AP), or any other type of interfacing device capable of operating in a wireless environment. When referred to hereafter, the terminology “base station” includes but is not limited to a Node-B, a site controller, an access point (AP), or any other type of interfacing device capable of operating in a wireless environment.

A power control scheme is disclosed for controlling both dynamically scheduled PUSCH and persistently scheduled PUSCH.

For power control for combined dynamically and persistently scheduled PUSCH, a general power control formula is given by Eq. (1). In a first embodiment, when an UL grant is configured for accumulation commands (for dynamically scheduled PUSCH), the WTRU combines the accumulation commands received in both the scheduling grant (SG) and the TPC-PDCCH<sub>PUSCH</sub>. Therefore, the function F(\*) in Eq. (1) can be expressed as

$$f[\Delta_{PUSCH}(i - K_{PUSCH})] = \sum_{m=0 \text{ or after previous reset}}^{i-K_{PUSCH}} (\Delta_{PUSCH,UL\_grant}(m) + \Delta_{PUSCH,TPC-PDCCH}(m))$$

where  $\Delta_{PUSCH,UL\_grant}(m)$  is the power control command received in the UL scheduling grant (SG) in subframe m (m=0 or after previous reset of the accumulation control to  $i-K_{PUSCH}$ ) and  $\Delta_{PUSCH,TPC\_PDCCH}(m)$  is the power control command received in TPC-PDCCH<sub>PUSCH</sub> in subframe m. Each term is an accumulation TPC command.

FIGS. 1A-1B show an example of a power control scheme when the UL grant is configured for accumulation commands. Referring to FIG. 1, the WTRU combines the accumulation commands received in the SG 120 and the TPC-PDCCH<sub>PUSCH</sub> 110, 130, 140 for performing dynamically scheduled PUSCH 160 and the SG 100 and the TPC-PDCCH<sub>PUSCH</sub> 110 for the persistently scheduled PUSCH 160.

In a second embodiment, shown in FIGS. 2A-2B, when an UL grant is configured for absolute commands, the WTRU resets the accumulation control function immediately after

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receiving an absolute TPC 200 and then combines the absolute TPC 200 with the accumulation control TPC-PDCCH<sub>PUSCH</sub> 210 for persistently scheduled PUSCH 250 and after receiving each absolute TPC 220 and then combines the absolute control with the accumulation control TPC-PDCCH<sub>PUSCH</sub> 230, 240. In this case, the function f(\*) in can be expressed as follows:

$$f[\Delta_{PUSCH}(i - K_{PUSCH})] = \Delta_{PUSCH,UL\_grant}(j) + \sum_{m=j}^{i-K_{PUSCH}} (\Delta_{PUSCH,TPC-PDCCH}(m))$$

where  $\Delta_{PUSCH,UL\_grant}(j)$  is the absolute power control command received in UL scheduling grant in subframe j, and j ( $j \leq i - K_{PUSCH}$ ) is the subframe index of the last absolute command and

$$\sum_{m=j}^{i-K_{PUSCH}} (\Delta_{PUSCH,TPC-PDCCH}(m))$$

is the sum of accumulation commands since the last absolute command.

If no power control step  $\Delta_{PUSCH}(k)$  (where k is 0 to any number) is provided on either the UL scheduling grant or on the TPC-PDCCH<sub>PUSCH</sub> in subframe k, then for absolute control,  $\Delta_{PUSCH}(k)$  in the equations above should be set to the latest value of  $\Delta_{PUSCH}$ , and for accumulation control,  $\Delta_{PUSCH}(k)$  in the equations above should be set to zero.

FIG. 5 shows the logical flow of an example embodiment. A connection is established at 500. The subframe index is set to the first subframe at 510. The current subframe is checked to determine if it contains the UL scheduling grant at 520. If the current subframe does not include the UL scheduling grant, then the subframe is checked to determine if it contains a TPC command in the signaling channel (TPC-PDCCH) at 540. If there is no TPC command, then processing continues at 520 after moving to the next subframe at 595. If the TPC-PDCCH contains a TPC command, then the accumulation function is updated (the TPC command is combined other TPC commands, if any) at 570 and processing continues at 580.

If the current subframe contains a UL scheduling grant, then it is further analyzed to determine if it also contains an absolute TPC command at 530. If the current subframe does contain the an absolute TPC command, the accumulation function is reset at 550 (any previous accumulation value is overwritten) and the absolute TPC command is combined with any subsequent accumulation commands, if they occur, at 570 and processing continues at 580. If the current subframe does not contain an absolute TPC command in the UL grant, the UL grant is checked to determine if it contains an accumulation TPC command at 560 and if so, the accumulation TPC command is combined with other TPC commands at 570 and processing continues at 580. If it is determined at 560 that the UL grant does not contain an accumulation TPC grant then processing continues at 520 after moving to the next subframe at 595.

At 580, if there is a PUSCH in the next  $K_{pusch}$  subframe then the updated accumulation function is used for calculating the transmit power for the PUSCH in the subframe at 590 and then processing continues at 520 after moving to the next



subframe at **595**. If there is no PUSCH in the next  $K_{pusch}$  subframe then processing continues at **520** after moving to the next subframe at **595**.

FIG. 3 shows a wireless communication system **300** including a plurality of WTRUs **310**, a base station **320**, and a Radio Network Controller (RNC) **330**. As shown in FIG. 3, the WTRUs **310** are in communication with the base station **320**, which is in communication with the RNC **330**. Although three WTRUs **310**, one base station **320**, and one RNC **330** are shown in FIG. 3, it should be noted that any combination of wireless and wired devices may be included in the wireless communication system **300**. For example, although the RNC **330** is shown in the wireless communication system **300**, the RNC **330** may not be included in a Long Term Evolution (LTE) system.

FIG. 4 is a functional block diagram **400** of a WTRU **310** and the base station **320** of the wireless communication system **300** of FIG. 3. As shown in FIG. 3, the WTRU **310** is in communication with the base station **320** and both are configured to perform a method of power control for dynamically and persistently scheduled PUSCH.

In addition to the components that may be found in a typical WTRU, the WTRU **310** includes a processor **315**, a display **320**, a receiver **316**, a transmitter **317**, and an antenna **318**. The processor **315** is configured to perform power control for dynamically and persistently scheduled PUSCH. The receiver **316** and the transmitter **317** are in communication with the processor **315**. The antenna **318** is in communication with both the receiver **316** and the transmitter **317** to facilitate the transmission and reception of wireless data. The display **320** displays appropriate information facilitating user operation of the WTRU and user interaction with the WTRU.

In addition to the components that may be found in a typical base station, the base station **320** includes a processor **325**, a receiver **326**, a transmitter **327**, and an antenna **328**. The processor **325** is configured to perform power control for dynamically and persistently scheduled PUSCH. The receiver **326** and the transmitter **327** are in communication with the processor **325**. The antenna **328** is in communication with both the receiver **326** and the transmitter **327** to facilitate the transmission and reception of wireless data.

Although the features and elements are described in particular combinations, each feature or element can be used alone without the other features and elements or in various combinations with or without other features and elements. The methods or flow charts provided may be implemented in a computer program, software, or firmware tangibly embodied in a computer-readable storage medium for execution by a general purpose computer or a processor. Examples of computer-readable storage mediums include a read only memory (ROM), a random access memory (RAM), a register, cache memory, semiconductor memory devices, magnetic media such as internal hard disks and removable disks, magneto-optical media, and optical media such as CD-ROM disks, and digital versatile disks (DVDs).

Suitable processors include, by way of example, a general purpose processor, a special purpose processor, a conventional processor, a digital signal processor (DSP), a plurality of microprocessors, one or more microprocessors in association with a DSP core, a controller, a microcontroller, Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs) circuits, any other type of integrated circuit (IC), and/or a state machine.

A processor in association with software may be used to implement a radio frequency transceiver for use in a wireless transmit receive unit (WTRU), user equipment (UE), terminal, base station, radio network controller (RNC), or any host

computer. The WTRU may be used in conjunction with modules, implemented in hardware and/or software, such as a camera, a video camera module, a videophone, a speakerphone, a vibration device, a speaker, a microphone, a television transceiver, a hands free headset, a keyboard, a Bluetooth® module, a frequency modulated (FM) radio unit, a liquid crystal display (LCD) display unit, an organic light-emitting diode (OLED) display unit, a digital music player, a media player, a video game player module, an Internet browser, and/or any wireless local area network (WLAN) module.

What is claimed is:

1. A wireless transmit/receive unit (WTRU) comprising:
  - a receiver and an associated processor configured to receive first and second type of control information; wherein the first type of control information includes transmit power command (TPC) information and scheduling information and the second type of control information includes TPC information and no scheduling information; and
  - a transmitter and an associated processor are configured when the first type of control information and the second type of control information is received in different subframes and the TPC information for the first and second type of control information is accumulation TPC information, to accumulate the TPC information of the first and second type of control information, and wherein the transmitter and the associated processor are configured to set the transmission power level for a physical uplink shared channel (PUSCH) in response to the accumulated TPC information.
2. The WTRU of claim 1 wherein the transmitter and the associated processor are configured to enable accumulation of TPC information and wherein the transmitter and the associated processor does not accumulate the TPC information when accumulation of TPC information is not enabled.
3. The WTRU of claim 1 wherein the TPC information of the first type of control information is configurable to be absolute power control information and wherein the transmitter and the associated processor are configured to not accumulate the absolute power control TPC information and set the transmission power level for the PUSCH in response to the absolute power control information.
4. The WTRU of claim 3 wherein the second type of control information is not configurable to include absolute power control information.
5. The WTRU of claim 3 wherein the transmitter and the associated processor are configured to reset accumulation of transmit power control information when the received TPC information is absolute power control information.
6. The WTRU of claim 1 wherein the receiver and the associated processor are configured to attempt to detect the second type of control information in each subframe except when the receiver and the associated processor are using discontinuous reception.
7. The WTRU of claim 1 wherein when the receiver and the associated processor receive accumulate TPC information of the first type of control information and the second type of control information in a same subframe, the transmitter and the associated processor are configured to accumulate the TPC information of the first type of control information and not the TPC information of the second type of control information for that same subframe.
8. A method for power control comprising:
  - receiving first and second type of control information, wherein the first type of control information includes transmit power command (TPC) information and sched-



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uling information and the second type of control information includes TPC information and no scheduling information;  
 receiving the first type of control information and the second type of control information in different subframes and the TPC information for the first and second type of control information is accumulation TPC information; accumulating the TPC information of the first and second type of control information; and  
 setting the transmission power level for a physical uplink shared channel (PUSCH) in response to the accumulated TPC information.

**9.** The method of claim **8** further comprising enabling accumulation of TPC information and wherein the TPC information is not accumulated when accumulation of TPC information is not enabled.

**10.** The method of claim **8** further comprising:  
 when the first control information includes absolute power control TPC information, not accumulating the absolute power control TPC information; and  
 setting the transmission power level for the PUSCH in response to the absolute power control information.

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**11.** The method of claim **10** wherein the second type of control information is not configurable to include absolute power control information.

**12.** The method of claim **10** further comprising:  
 resetting accumulation of transmit power control information when the received TPC information is absolute power control information.

**13.** The method of claim **8** further comprising:  
 attempting to detect the second type of control information in each subframe except during discontinuous reception.

**14.** The method of claim **8** further comprising:  
 receiving accumulation TPC information of the first type of control information and the second type of control information in a same subframe; and  
 accumulating the TPC information of the first type of control information and not the TPC information of the second type of control information for that same subframe.

\* \* \* \* \*

UNITED STATES PATENT AND TRADEMARK OFFICE  
**CERTIFICATE OF CORRECTION**

PATENT NO. : 8,260,341 B2  
APPLICATION NO. : 12/261235  
DATED : September 4, 2012  
INVENTOR(S) : Shin et al.

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

ON THE TITLE PAGE

Item (56) OTHER PUBLICATIONS, page 1, on the eighteenth line of this section, before “36.213”, delete “TA” and insert therefore --TS--.

Item (56) OTHER PUBLICATIONS, page 2, right column, on the ninth line of this section, after “channels and modulation””, delete “0”.

IN THE SPECIFICATION

At column 1, line 66, after “ $10\log_{10}(M) + P_o + \alpha$ ”, delete “ $P_L$ ” and insert therefore --PL--.

At column 2, line 53, after “both”, delete “PUSCH” and insert therefore --PUSCHs--.

At column 2, line 54, after “control the two”, delete “PUSCH” and insert therefore --PUSCHs--.

At column 4, line 6, after “the function f(\*)”, delete “in”.

At column 4, line 45, after “command is combined”, insert --with--.

At column 4, line 51, after “contain”, delete “the”.

IN THE CLAIMS

In claim 7, at column 6, line 57, after “processor receive”, delete “accumulate” and insert therefore --accumulated--.

Signed and Sealed this  
Sixteenth Day of April, 2013



Teresa Stanek Rea  
Acting Director of the United States Patent and Trademark Office